Agent-based Dynamic Scheduling of Daily Activities

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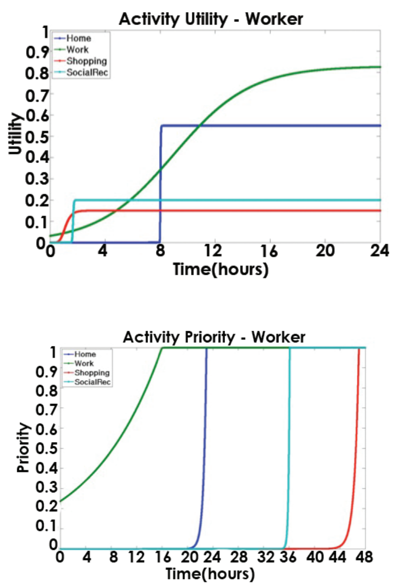
An agent-based optimization approach for dynamic activity schedule generation has been developed as part of the DHS NISAC infrastructure modeling effort. The supporting functionality for choosing activity locations and activity execution operate concurrently. As a simulation, daily activity schedules for individual agents are generated based on their demographics and the utilities, priorities, and time constraints of a chosen set of activities. Traditional agent-based technology and numerical methods are combined. This is part of a larger effort to understand the interdependencies among national infrastructure networks and their demand profiles, which emerge in baseline and emergency scenarios. It operates as a standalone model for population analysis, and can be coupled with other infrastructure models.

Detailed large-scale infrastructure simulations of demand and disaster response require synthetic populations with realistic daily activities. Census-based agents replaying static activity schedules drawn from transportation surveys in a "ground-hog day" fashion have been shown to work well in practice. Here we present an enhanced hybrid agent approach of dynamically scheduling activities using rules, utilities, constraints, priorities, and optimization.

Fig.1. Example utility and priority functions.



Everyday life without major disruptions due to emergencies or natural disasters has a regularity or rhythm associated with it. We engage in different activities on different temporal scales, such as daily, weekly, monthly, or yearly. Home activities are a daily occurrence. Work is performed some number of times per week. Children and youth attend school on weekdays, but not weekends. Our shopping and social activities may be concentrated on weekends or fit around other activities, while the regularity of medical and service appointments may only be a few times per year.

Static one-day activity schedules have been the standard for infrastructure simulations and are still in use today. TranSims activity generation creates static ground-hog-day household schedules based on the National Household Transportation Survey and 2000 US Census data [1]. The single-day schedules have been extensively used in the simulation of telecommunication networks [2] and transportation networks [3]. Cycled daily schedules have been used for simulations of epidemic mitigation scenarios [4] where individuals abandon their usual schedules when ill and stay home. In a study of social contact patterns and their effect on the spread of disease, weekday schedules were further distinguished from weekends and holidays by replacement of work or school with home for a portion of the population [5]. The need for multiple-day schedules and schedules that can readjust when changes occur (minor or major) requires a more dynamic approach.

The ActivitySim model provides activity scheduling for synthetic populations as a large-scale hybrid agent-based discrete event simulation (DES). The term "hybrid" is used due to the combination of agents, DES, and mathematical methods. The supporting functionality for choosing activity locations and activity execution operates concurrently. This improves upon an early version with basic functionality [6]. As a simulation, daily activity schedules for individual agents are generated based on their demographics and the utilities, priorities, and time constraints of a chosen set of activities. Utility is dependent on the duration of an activity, while priority is based on the longest time allowed between instances of an activity (see Fig. 1). Utility increases with a longer duration, up to a limiting or maximum useful duration. As an activity's priority increases, it becomes more likely to be scheduled. Scheduling is driven by an optimization loop composed of a meta-heuristic, objective function and end condition. The meta-heuristic uses operators (e.g., Delete-IncreaseDuration, AdjustDuration, Substitute, DecreaseDuration-Insert, Append) to add or change activities within a time-window considering constraints and priorities. The objective function takes into account utilities, priorities, and travel time when evaluating a schedule. Schedules are produced activity-by-activity, drawn from a set based on an agent's demographics. The agent-based approach allows us to generate demand shocks as an emergent property of the simulation for baseline and emergency scenarios. It operates as a standalone model for population analysis, and can be coupled with other infrastructure models.

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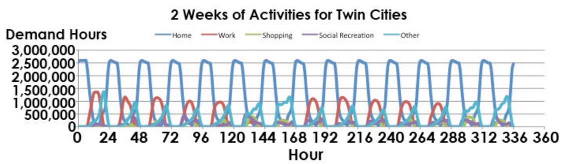
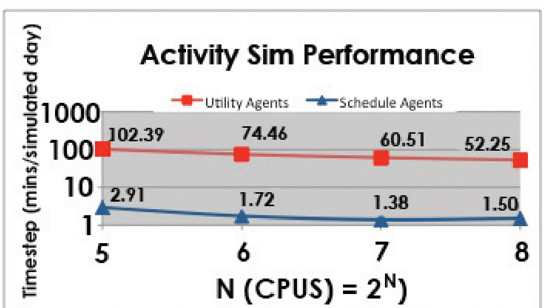


Fig. 2. Population activity participation.

The main concepts are person, household, location, and zone. A person can be part of a synthetic population based on US census data, another country, a demographic, or completely fictitious. A household is assigned for each person and serves as a home base for families or groups of individuals. A location can represent a geo-located business or home as a building or room. A location could alternatively represent a group of businesses in a geographic area such as a county, city, or state. A zone represents an aggregate of locations over a larger geographic area. For example, when locations are individual businesses, zones can be groups of locations in the same block group. Networks of zones with user-defined connectivity are used in selecting activity location choices.

An overall enumeration of activities must be defined for the person population dependent on the scenarios being considered. Activities can be very general (e.g., home, work, elementary school, junior high school, high school, shop, dine out, social recreation), more specific (e.g., sleep, personal care, breakfast, lunch, dinner, food shopping, morning work, afternoon work), or mixed. Subsets of activities, as activity-sets, are defined for demographic groups or other partitionings of the person population. For example, demographic groups based on age, school situation, and worker-status can be defined for young children (0-5), elementary school youth (6-10), junior high school youth (11-13), high school youth (14-17), college, non-workers, workers, and seniors. There can be common activities across activity-sets (e.g., home, shop, social recreation). A name, duration, start, and end time constraints, utility function (e.g., sigmoid) and parameters, priority function (e.g., sigmoid) and parameters, travel time, and a weekend factor are provided for each activity in each activity set. Tuning is required to set the utility and priority function parameters. Different demographic groups may have the same activities, but different time constraints and priorities

Fig. 3. Performance.



Agent processing is driven by meta-rules. There are three types of actions that can occur in an overlapping fashion. They are: (1) distributed activity location choice–where each person collects their set of favorite locations for each of their activities, (2) dynamic scheduling and rescheduling–where activities are scheduled and optimized, and (3) activity execution–where persons perform their scheduled activities. In coupled models, the execution of activities can be used to drive different model layers, such as transportation or other infrastructure demands.

ActivitySim was used to simulate the daily activities (the general set described above) of a Twin Cities, MN synthetic population composed of 2.6 million individuals, with about one million households and more than 480 thousand different locations. The simulation was executed on the LANL Institutional Computing Coyote cluster and was run for two simulated weeks. Figure 2 shows the population participation for a number of daily activities (starting on a Monday) for weekdays and weekends. Regularity is seen in home, work, and school activities and less for the others. Activity participation and duration is seen to change as the week progresses.

This utility-based scheduling is compute-intensive, but still exhibits strong scaling. Figure 3 shows runtime performance in comparison to pre-calculated schedules for Twin Cities.

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[3] Thulasidasan, S., et al., “Accelerating Traffic Microsimulations: A Parallel Discrete-Event Queue-Based Approach for Speed and Scale,” *Proc 2009 Winter Simulation Conf* (2009).
[4] Mniszewski, S., et al., *Comput Math Organ Theor* **14,** 209 (2008).
[5] Del Valle, S., et al., “Dynamic Contact Patterns” in *Realistic Social Networks, Social networks: Development, Evaluation and Influence,* Nova Science Publishers (2008).
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